

ment 110, then the processing unit 124 outputs a command to the tactile control module 127 specifying the output of an electrical signal having a voltage magnitude and period set such that frictional force corresponding to the finger's motion is produced. In response to this command, the tactile control module 127 generates an electrical signal having the set voltage magnitude and period, and then applies the generated electrical signal to the electrode sheet 111 of the operable element 110.

[0089] If, for example, the user's finger 150 is in a region of the operable element 110 where nothing is being displayed, then the processing unit 124 outputs a command to the tactile control module 127 for stopping the application of voltage. In response to this command, the tactile control module 127 terminates output of the electrical signal to the electrode sheet 111 of the operable element 110. By means of this process, the user experiences frictional force and vibration as user interface feedback when moving his or her finger in a region where a switch, slider, or other element is displayed on the operable element 110, but the user does not experience any particular tactile sensation when his or her finger is touching a portion where nothing is displayed.

[0090] In this way, in an embodiment of the present invention as configured above, the commands from the processing unit 124 are modified according to factors such as the position, motion, and applied pressure of the user's fingers, with the tactile control module 127 subsequently controlling the electrical signal to be applied to the electrode sheet 111 of the operable element 110. As a result, it becomes possible to vary the frictional force in accordance with factors such as the position, motion, and applied pressure of the user's finger, thereby enabling the user to experience diverse user interface feedback.

[0091] Furthermore, in an embodiment of the present invention as configured above, the operable element 110 may have a two-layer structure made up of an electrode sheet 111 and an insulator 112, and may be configured without disposing a large number of electrodes as described earlier with reference to FIG. 1. Consequently, it is possible to miniaturize the above configuration and significantly reduce costs. Moreover, the operable element may also be configured having a flexible structure, and may be utilized in a variety of devices.

[0092] In an embodiment of the present invention as configured above, it is possible to independently modify the voltage and frequency to be applied to the electrode sheet 111 of the operable element 110, thereby enabling the user to experience a variety of user interface feedback variations. It is thus possible to appropriately modify the voltage and frequency in accordance with the conditions whereby the user performs input operations with respect to the operable element 110, and in accordance with the information displayed on the operable element.

[0093] However, it should be appreciated that the configuration described with reference to FIGS. 2 to 5 is merely one embodiment of the present invention, and that other configurations are also possible wherein various sensors are used to acquire user information or similar data other than that of the above configuration. For example, another embodiment may be configured to detect the position and motion of the user's finger by means of components such as an optical sensor, a laser sensor, or a camera. Furthermore, the operable element

is modifiable for use in a variety of configurations, such as in the flexible structure or the display described above.

(2) Specific Examples of User Interface Feedback Apparatus

[0094] Hereinafter, several specific examples of the user interface feedback apparatus of the present invention will be described with reference to FIGS. 6 to 10B. The following two exemplary configurations will be described in sequence:

[0095] (2-1) Two-dimensional (2D) user interface feedback apparatus

[0096] (2-2) One-dimensional (1D) user interface feedback apparatus

(2-1) Two-Dimensional (2D) User Interface Feedback Apparatus

[0097] First, a two-dimensional (2D) user interface feedback apparatus will be described with reference to FIG. 6. The two-dimensional user interface feedback apparatus is principally similar in configuration to that described with reference to FIGS. 2 to 5, wherein the operable element has been integrated with an LCD or similar display, for example. FIG. 6 illustrates the configuration of the operable element 200 only. The operable element 200 has a laminar structure wherein a transparent electrode sheet 211 and a transparent insulator 212 have been stacked on top of a transparent sheet 220 made of a material such as glass or plastic. The bottom transparent sheet 220 is a component of an LCD, for example.

[0098] Such a configuration is realizable simply by forming the transparent electrode sheet 211 and transparent insulator 212 on top of an existing display. The transparent electrode sheet 211 and the transparent insulator 212 in the configuration shown in FIG. 6 correspond to the electrode sheet 111 and the insulator 112 in the configuration shown in FIG. 2. Although FIG. 6 shows only the operable element 200, processing modules similar to those of FIG. 2 are connected to the operable element 200.

[0099] Factors such as the position and pressure of the user's finger 250 are detected by sensors, a voltage and frequency are determined in accordance with the information detected by the sensors, and an electrical signal is fed to the transparent electrode sheet 211. Note that at this point, processing may also be conducted to determine the motion of the user's finger 250 (i.e., motion information) from changes in the position information detected by the sensors, and then determine a voltage and frequency in accordance with the motion information results. When the user's finger 250 is moved over the transparent insulator 212, friction is felt whose magnitude varies according to the electrical signal fed into the transparent electrode sheet 211. The user experiences this friction as user interface feedback in response to the user's operation, such as the operation of a switch or slider displayed on the operable element 200 by the user's finger 250.

[0100] As described earlier, the voltage and frequency of the electrical signal output to the transparent electrode sheet 211 may be set to arbitrary values in accordance with factors such as the position, motion, and pressure of the user's finger 250. It is possible to execute processing such that, if the user's fingertip is touching the position of an element such as a switch or slider displayed as an image or icon on the operable element 200, then an electrical signal having predetermined voltage and frequency values set in accordance with particular images or icons is input. In contrast, if the user's fingertip